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Mechanical Engineering

Team 19F15
Team SunTrac

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Subject: ER's and TP's Revamp Memo

Introduction

This memo contains the updated engineering requirements and testing procedures for the Suntrac USA Capstone team. To recap, the aim of this project is to redesign SunTrac USA's braze welding jig such that it can be feasibly used to manufacture their 4', 6', and 8' manifold variants. The customer requirements (CR's) Suntrac USA established for the team were used to generate engineering requirements (ER's) and the team deduced testing procedures (TP's) that would prove the design state is capable of satisfying the ER's. All changes to the design have been to best reflect the engineering requirements and customer needs that were documented in September of 2019. ER #3 was changed because the corresponding CR was updated. Initially it was to minimize cost, but a budget of $1,500 dollars had been allotted. Like how each are presented, firstly in this memo, the CR's are stated then the more detailed ER's corresponding to the CR's are. The TP's that would verify the ER's are detailed in the next section. Lastly, a conclusion summarizes the most important ER's and TP's.

1 Customer Requirements (CR's)

The customer requirements in this project were taken directly from SunTrac, USA. The team spoke directly to the client and produced the appropriate CR's to satisfy all the customer needs. Spring semester, when the team met with SunTrac, the client required some design changes that they would like to be implemented on the final product. The changes that were required did not affect the main objective of the project, which is to produce a braze-welding jig that can hold SunTrac's three product variations. Since the objective was not affected, the CR's will stay the same. The changes that were made were on the design element and not on the original requirements that resulted in that design. Therefore the teams customer requirements are as follows:

- Safe to Operate
- Cost under $1600
- Fits all product sizes (4',6', and 8')
- Machinable parts
- Fits in 5' x 5' square
- Allows easy access to all copper joints
- 8+ locking positions
- Durable and Robust Design
- Reliable Design

A minor modification that might be noticable is that the cost has a fixed budget of $1600 now, while previously the CR was "cost within budget". This is due to the fact that the budget is known instead of the assumption of the cost being under it. Other than this minor adjustment, the CR's remain unchanged while still fulfilling the customer goals.

2 Engineering Requirements (ER's)

For each customer requirement stated in the previous section, an engineering requirement is formed. The purpose of an ER is to verify and set a target value or tolerance for each CR used. Since the CR's did not change, the engineering requirements stayed the same to satisfy them. The parameters and tolerances however, varied slightly since more analytical analysis has been conducted. Any changes that have been made will be discussed along with the reason that led to its alteration below.

2.1 ER #1 (Same): Melting Temperature

2.1.1 ER #1: Melting Temperature Target = 1400 oC

The process of braze welding involves very high temperatures to melt and adhere the copper. Conductive heat transfer to the Jig is certainly unavoidable so it needs to be made out of material that can withstand this temperature. Being a robust and reliable design involves satisfying this requirement.

2.1.2 ER #1: Melting Temperature Tolerance = -300 oC

Locally where the braze welding occurs, the temperature is approximately 1400 degrees celsius, but heat transfer out of the system is significant since copper is a very thermally conductive material, so this temperature does not reach the Jig itself. The melting temperature of the material for the Jig face can certainly be above this limit, but should not be more than 300 degrees beneath this target.

2.2 ER #2 (Same): Force to Rotate

2.2.1 ER #2: Force to Rotate - Target = 13 Newtons

The Jig should not provide much difficulty under operation, so when rotating the face it should be done with relative ease. However if it should freely rotate this would be a safety hazard since it has a large swing arm and is heavy. So the team designated that there should be some, but not significant, resistance to rotation. Then since the apparatus is symmetrical about to axes, it is balanced so gravity shouldn't pose much of an effect to accelerate the swing. This involves the use of a bearing or bushing to support the axle that the Jig face is supported on.

2.2.2 ER #2: Force to Rotate- Tolerance = 3 Newtons

When pushed at either end of the Jig, the moment arm is significant about the axis due to the jig size. A proper bearing or bushing can fulfill this tolerance to allow the Jig to be easy to operate but not unsafe.

2.3 ER #3 (Modified): Cost under $1,600

2.3.1 ER #3: Cost under $1,600 - Target = $1,500

The client was able to increase the overall budget to $1,500 from the $1,000 that was set last semester.

This number is based on the fact that $1,500 was spent on their 6 foot jig, which they approved as a reasonable cost. The team believes the cost should not exceed $1,250 based on the current Bill of Materials. This so far leaves room for unexpected contingency costs.

2.3.2 ER #3: Cost under $1,600 - Tolerance = + $150 / - any

The maximum cost for the project materials is now set at $1,500 and the team decided that the maximum should be $1,600. But the team is set to design towards only using $1,250 to allow a contingency of $250 and a maximum contingency of $350.

2.4 ER #4 (Same): Number of Compatible Products

2.4.1 ER #3: Number of Compatible Parts - Target = 3 Product Variations

Suntrac USA employs three lengths of manifolds to be constructed (4', 6', and 8' lengths). Thus, the jig is designed to configure for each of the manifold configurations and maintain tolerances.

2.4.2 ER #3: Number of Compatible Parts - Tolerance = +/- 0

Since only these three lengths of manifolds will be constructed, there is no need for the Jig to do otherwise.

2.5 ER #5 (Same): Standard Parts

2.5.1 ER #3: Standard Parts - Target = 90% of Parts

With regard to design reproducibility, components that make up the Jig are to be comprised of standardized parts, that way should SunTrac want more Jigs, parts can be purchased without fulfilling custom orders, this helps keep costs low. However, the Jig fulfills a rather specific goal with some special tolerances so there are some parts that need to be custom made.

2.5.2 ER #3: Standard Parts - Tolerance = 10% of Parts

There are components like the stand and the telescoping tubes that comprise the Jig face which are made from standardized parts.These are square extrusions of steel tubes that are commonly and cheaply produced. They are not manufactured in these exact lengths length but Suntrac USA is capable of making these cuts to length. Other components like the power screws and end plate are designed to hold specific pieces of the manifolds to within a toleranced length, so these parts will need to be specially machined to fulfill that requirement.

2.6 ER #6 (Same): Footprint

2.6.1 ER #3: Footprint - Target = 5ft x 5ft

Much like with their currently employed jig design, Suntrac is willing to utilize a 5 by 5 foot square of floor space for the Jig to occupy. Their facilities however have high ceilings so height requirement is not needed.

2.6.2 ER #3: Footprint - Tolerance = + 1ft x 1ft

This requirement is a relatively loose one that the team needs to follow, but necessary considerations should be made to satisfy it. A maximum footprint of 6 by 6 ft space should be easily attainable.

2.7 ER #7 (Same): Degree of Rotation

2.7.1 ER #3: Degree of Rotation - Target = 720 degrees

It is intended to have the jig rotate indefinitely. This sort of requirement is most achievable by using a cylindrical axis as part of a hub

2.7.2 ER #3: Degree of Rotation - Tolerance = 360 degrees

Considering how the brazing process is done, only one full rotation of the Jig face needs to be done.

2.8 ER #8 (Same): Number of Locking Positions

2.8.1 ER #3: Number of Locking Positions - 12

It is crucial that the Jig is capable of locking in a variety of positions to allow for easy access to all the copper points. Yet the Jig cannot freely rotate, so a worker can braze weld safely. The current jig allows for six locking positions (three on each side) but this amount has been found to be restricting and they would like more locking positions.

2.8.2 ER #3: Number of Locking Positions - Tolerance = - 4 / + any

Suntrac has no problem with as many locking positions as possible. Their current braze worker stated that at least 12 would be suitable but would be fine with eight.

2.9 ER #9 (Same): Durability

2.9.1 ER #3: Durability - Target = 5 years

Longevity is particularly important for the Jig since it is such a crucial component in Suntrac's manufacturing process. They requested that the Jig last for several years and incur minimal maintenance operations. The team interpreted this as at least five years without maintenance.

2.9.2 ER #3: Durability - Tolerance = - 1 year

Of course if the design is very reliable it would not have to be operated on for even more years. Establishing a limit is necessary, and the team decided at least four years of withstanding continuous operation is desirable.

2.10 ER #10 (Same): Tolerance/ Error

2.10.1 ER #3: Tolerance/ Error - Target = 0

Zero error means that the Jig is capable of manufacturing the copper manifold to the specified dimensions perfectly. Perfect tolerances are desirable but of course unattainable. Gd&t principles in our design must be applied in such a way to have the error approach zero. This ER is important because if a manifold is not manufactured within the tolerances it is unusable.

2.10.2 ER #3: Tolerance/ Error - Tolerance = +/- 1/16”

The manifold itself gets inserted into a thermally insulated box as part of Suntrac’s product. The brass brackets on each end of the copper manifold are intended to be close to the opposing walls within this box. Then the mirrors that concentrate solar light on to the copper pipes are also placed close together and under no circumstance can interfere with each other. The tolerance utilized here translates to the Jig and how it's manufactured so that it can produce manifolds with this tolerance.

3 Testing Procedures (TP’s)

This section discusses the testing procedures that will be developed to ensure the Engineering Requirements have been satisfied. It is important to have these tests as they will determine if the device is durable and also eliminate the chance of the device breaking any standards, codes, or regulations. For the purpose of this project, the team has created five different testing procedures. First, the objectives of these tests will be discussed and also the details about how these tests will be performed. Next, details about the testing equipment used along with the means of acquiring this equipment will be analyzed. Finally, the schedule needed to perform these tests will be listed as well as the engineering requirements that they satisfy. All testing will be performed at SunTracs’ manufacturing facility, all resources will be sourced from their warehouse.

3.1 Testing Procedure 1: Critical Length

3.1.1 Testing Procedure 1: Objective

There are three objectives for this test. The first objective is to test whether a large centrifugal force will change the critical length of the jig. The second objective is to see if each size copper manifold will fit in the braze welding jig. The third objective is the test if the jig will rotate a full 360 degrees. This test includes taking a length measurement of the jig at the four foot configuration before changing the jig to the eight foot configuration and locking it vertically. The next step is to release the locking mechanism before spinning the jig as fast as the user can manage. Once the jig comes to a stop, the final step is to set the jig back in the four foot configuration and re-measuring the length. This test is conducted because it satisfies all the above objectives as one test. If there are no differences in lengths, the Error requirement is satisfied. If all three configurations of copper manifolds fit in the jig the Versatility requirement is satisfied. Finally, if the jig rotates a full 360 degrees the Degree of Rotation requirement is met.

3.1.2 Testing Procedure 1: Resources Required

The required resources for this test include the completed full scale braze welding jig as well as the SunTrac manufacturing facility, the SunTrac team, Stu Siebens, and a tape measure. The completed jig needs to be bolted to the floor and therefore needs the manufacturing facility. The team and Stu Siebens will be there to monitor the experiment and a tape measure will be used to measure the change the critical length of the braze welding jig.

3.1.3 Testing Procedure 1: Schedule

This test will take approximately 15 minutes to conduct and record. If any additional trials are requested it will take an additional 15 minutes per trial. This test will likely be run on March 16 when the full scale braze welding jig is assembled and installed. This test is dependent on manufacturing space and available free time of Stu Siebens and the SunTrac team and therefore may change the date to fit schedules. This will fit in our schedule by adding it to the gantt chart at the beginning of the semester.

3.1.4 ER's Tested

This test will prove that the tolerance/error, number of compatible products, and degree of rotation engineering requirements are satisfied (ER's 4,7,10).

3.2 Testing Procedure 2: Heat Exposure

3.2.1 Testing Procedure 1: Objective

There are two objectives for this test. The first objective is to measure the temperature of the braze welding jig in a worse case scenario. The second objective is to measure how much the metal deforms at different times in the heating process. This test includes taking multiple one inch pieces of the metal square tubes that are used in the face of the braze welding jig and placing them on a hard surface. Using a brinell hardness tester the team will then measure the hardness at room temperature. After this test the team will sequentially heat up each piece of metal using an oxy-propane torch and test the hardness every 30 seconds until 300 seconds has elapsed. During this time period a temperature sensor is used to measure the temperature of each piece of metal. If the temperature does not reach the temperature that steel melts the Melting Temperature requirement is satisfied.

3.2.2 Testing Procedure 1: Resources Required

The required resources for this test include 11 one inch pieces of steel square tubing, an oxy-propane torch, brinell hardness tester, calculator, stopwatch, SunTrac team, Stu Siebens, and an available lab location. More personal may be included on this list if SunTrac employees want to watch the test take place.

3.2.3 Testing Procedure 1: Schedule

The required time to conduct this lab is approximately 20 minutes if there are no complications in the data analysis. The schedule for this test depends on when the needed material and lab equipment can be procured. The likely date in which this lab will take place is March 16, 2020. This will fit in our schedule by adding it to the gantt chart at the beginning of the semester.

3.2.4 ER's Tested

This test will prove that the melting temperature and durability engineering requirements are satisfied (ER's 1,9).

3.3 Testing Procedure 3: Final Cost

3.3.1 Testing Procedure 1: Objective

There are two objectives for this test. The first objective is to ensure that the cost is within the teams budget. The second objective is to avoid using custom parts when at all possible. This test includes looking over the bill of materials and ensuring cost are minimized. The second part of this test is calling the manufacturers to finalize the quotes for material and begin purchasing the supplies. If the final amount quoted is within the allowed budget the Cost engineering requirement is met. If custom parts are minimized in the quoted material the Standardized Part engineering requirement is also met.

3.3.2 Testing Procedure 1: Resources Required

The resources needed to complete this test include the SunTrac team, cell phone, $1600.00 budget, bill of materials, and verbal confirmation from Stu Siebens. Since this test requires the spending of the budgeted money the Director of Engineering at SunTrac USA must approve the bill of materials. Any setting with a WiFi connection will suffice for this test.

3.3.3 Testing Procedure 1: Schedule

The required time to conduct this test will likely be several hours depending on how long it takes to finalize quotes over the phone. This test must be completed before all other tests and therefore must be completed as soon as possible. To ensure the bill of materials if finalized the test will most likely take place February 16, 2020. This will fit in our schedule by adding it to the gantt chart at the beginning of the semester.

3.3.4 ER's Tested

The engineering requirements that are satisfied in this test include the cost requirement and standardized parts requirement (ER's 3,5).

3.4 Testing Procedure 4: Rotation Assessment

3.4.1 Testing Procedure 1: Objective

There are two objectives that must be met in this test. The first objective is to test if a person of average strength can create a force strong enough to cause the braze welding jig to rotate. The second objective is to test if all available locking positions are free of debris and can successfully secure the jig. This test first includes attaching a force gauge on the bottom left edge of the rotating subassembly of the braze welding and slowly pulling the other edge of the braze welding jig until the jig begins to rotate. The force to overcome the static friction should be displayed on the force gauge. The next portion of this test is locking the jig at every locking position and applying a five pound force perpendicular to the lever arm of the jig. The lock should resist the applied force and keep the jig stationary. If it takes less than 10lbs of force to rotate the jig the Force to Rotate requirement is satisfied.If the jig can resist a 10lb weight while in each locking configuration the Adaptability requirement is also met.

3.4.2 Testing Procedure 1: Resources Required

The required resources for this lab include the SunTrac team, Stu Siebens, the full scale braze welding assembly, force gauge, 10lb weight, and SunTrac's manufacturing facility. The team is needed to conduct the experiment while Mr. Siebens is needed to confirm the results. The completed braze welding jig will be required to conduct the test and it will need to be bolted to the floor of the SunTrac manufacturing facility to resist any shear or moment. More members of SunTrac's executive board may attend if they have the time.

3.4.3 Testing Procedure 1: Schedule

This test will take approximately one hour to conduct and record. This test will likely be run on the 16th of March 2020 when the full scale braze welding jig is assembled and installed. This test is dependent on manufacturing space and available free time of Stu Siebens and the SunTrac team and therefore may change date to fit schedules. This will fit in our schedule by adding it to the gantt chart at the beginning of the semester.

3.4.4 ER's Tested

This test ensures that the engineering requirements of force to rotate and number of locking positions are satisfied (ER's 2, 8).

3.5 Testing Procedure 5: Final Dimensions

3.5.1 Testing Procedure 1: Objective

The objective of this test is to ensure the footprint area is less than a 5' by 5' area. This test includes measuring the area of the triangle created from the three legs of the braze welding jig. If the area is less than $25ft^2$ The Footprint engineering requirement is satisfied.

3.5.2 Testing Procedure 1: Resources Required

The required resources for this lab include the SunTrac team, Stu Siebens, the full scale braze welding assembly, tape measure, calculator, and SunTrac's manufacturing facility. The completed braze welding jig will be required to conduct the test and it will need to be bolted to the floor of the SunTrac manufacturing facility to resist any shear or moment. More members of SunTrac's executive board may attend if they have the time.

3.5.3 Testing Procedure 1: Schedule

This test will take approximately 10 minutes to conduct and record. This test will likely be run on MArch 16, 2020 when the full scale braze welding jig is assembled and installed. This test is dependent on manufacturing space and available free time of Stu Siebens and the SunTrac team and therefore may change date to fit schedules. This will fit in our schedule by adding it to the gantt chart at the beginning of the semester.

3.5.4 ER's Tested

This test will prove that the footprint engineering requirement is satisfied (ER 6).

Conclusion

The nature of the SunTrac design team's project is one which seldom requires changes to the fundamental design stage as the overarching objective is firm, that is to produce an assembly which allows for the convenient brazing of three variations of copper manifold. That being said, the customer needs remain unaltered with the exception of a slight modification in the project budget. This modification has altered the cost engineering requirement's target (from $1,000 to $1,500), while the tolerance remains the same. This slight alteration is substantial as the cost engineering requirement has a relative technical importance of one, meaning it is the most impactful ER and its influencing variables are more heavily considered than others. The testing procedure accompanying this most important ER is the Final Cost, entailing of reviewing the Bill of Materials and manufacturer quotes to ensure the project budget is under the $1,500 target and surely under the maximum allotted $1,600. Versatility is the second most ranked ER, being the ability for the Jig assembly to accept the required three product variations. This requirement is unaltered and satisfied through the Critical Length testing procedure, which as well tests for degree of rotation and error, error being the fourth most significant engineering requirement. Lastly, the durability of the Jig is another important ER, being the third most significant in regards to relative technical importance. This ER will be proven to be satisfied through the process of the Heat Exposure testing procedure, where the Jig face material's Brinell Hardness will be tested with the systematic continual addition of heat to ensure negligible deformity. In summary, all customer requirements, engineering requirements, and testing procedures remain unaltered with the exception of the budget modification, resulting in a slight change of ER #3.